TOWNSHIP OF TERRACE BAY
BACTERIA ISOLATION SURVEY

MUNICIPAL AND PRIVATE ABATEMENT SECTION
NORTHWESTERN REGION
ONTARIO MINISTRY OF THE ENVIRONMENT

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January, 1983

TABLE OF CONTENTS

SUMMARY

The Ontario Ministry of the Environment conducted a water quality evaluation, along a 15-20 kilometre stretch of Lake Superior shoreline, adjacent to the Township of Terrace Bay, during the summer of 1981.

Lake Superior waters were sampled both to the east and to the west of the municipal water intake, in an effort to determine the source of elevated levels of recurring bacteria in the Terrace Bay raw water supply.

Elevated bacterial levels were traced back to the effluent discharged by Kimberly-Clark of Canada Limited. The effluent is discharged to Blackbird Creek and ultimately to Moberley Bay, approximately 12 kilometres northeast of the water intake.

Although significantly elevated bacterial levels have been detected in the raw water supply, the chlorine treatment at the pumping station continues to provide a safe drinking water to the community of Terrace Bay.

All the measured organic constituents were virtually undetectable 2 kilometres from the effluent outfall. Of the inorganic parameters, sodium and chloride were the only ones found above background concentrations outside Jackfish Bay.

INTRODUCTION

The domestic water supply for the Township of Terrace Bay is provided by Kimberly-Clark of Canada Limited. Water is obtained from Lake Superior for both the townsite and the pulp mill operation.

Raw water samples are collected at the Kimberly-Clark pumphouse once each week. For purposes of this survey, additional samples were collected during August and September, 1981.

Lake Superior waters in the vicinity of the water intake are normally virtually free of bacteria, however, abnormally high levels of bacteria were detected during the months of July and August. Since the township water supply is chlorinated, the bacteria in the raw water did not present a problem.

The Ministry's concern over the source of bacteria prompted a study during the summer of 1980. Data collected at that time suggested that the effluent discharged from Kimberly-Clark's pulp mill was responsible for the bacteria.

In an effort to provide a better bacterial profile in Lake Superior and thereby pinpoint the source, a follow-up study was conducted during the summer of 1981.

DESCRIPTION OF STUDY AREA

The Township of Terrace Bay is located on Highway #17 approximately 250 km east of Thunder Bay. Kimberly-Clark's pumphouse is located on the shore of Lake Superior, southeast of the Terrace Bay townsite. Chlorination is the only treatment provided. A 90 cm trunk main extending from the pumphouse to the pulp mill north of the town, provides a 30 cm feeder line to Terrace Bay's distribution system. The pumphouse is capable of supplying 109 m^3/min. from any two of the three pumps. In the event of system failure, an alternate supply from Hays Lake (northwest of the town) can be directed to the distribution system.

POTENTIAL SOURCES OF BACTERIA

1. A channel, constructed adjacent to Kimberly-Clark's mill, receives approximately 100,000 m^3 of both pulp effluent and "treated" sewage. The channel empties into Blackbird Creek, which meanders for approximately 15 kilometres before discharging into Moberley Bay of Lake Superior (Figure 1). The discharge is approximately 12 km northeast of the water

intake. A counter-clockwise current in Lake Superior, has the potential to draw the discharge westward past the water intake. Winds also play a role in directing the effluent plume.

2. A small stream (Creek A; Figure 1), which flows through the eastern extremity of the townsite, drains an abandoned landfill site prior to discharge to Lake Superior. This discharge is immediately east of the water intake. Water flow during the summer months is extremely low.

3. Domestic sewage from the Township of Terrace Bay is treated by two discrete systems. Domestic sewage from Terrace Heights is treated by a small extended aeration facility. Sewage from the remainder of the community is directed to an exfiltration lagoon. The lagoon lies adjacent to a small stream (Creek B; Figure 1), which in turn empties into Lake Superior. There is no measurable impact of the lagoon leachate on Lake Superior. In addition, the discharge is located "downstream" with respect to established lake currents.

4. West of the town, the Aguasabon River drains Hays Lake to Lake Superior. Flow is regulated by a dam and during the summer months, flow through the dam is extremely low.

METHODS

Prior to October, 1980, samples for bacteriological analyses were submitted to the Ministry of Health Laboratory in Thunder Bay on a weekly basis. Since October, 1980, weekly bacteriological analyses have been conducted at the Ministry of the Environment Regional Laboratory in Thunder Bay.

Fifteen water sample locations were selected on Lake Superior, extending from east of Jackfish Bay, westward to Terrace Bay (Figure 1). All sites were sampled for bacteriological activity on June 22, 23, 24 and 25, 1981. Five of the above

sites were also selected for the measurement of basic water quality parameters (Figure 1). Concurrent with this sampling period, representatives of this Ministry's Water Resources Branch, Toronto, conducted an intensive survey of the water quality within Moberley and Jackfish Bays (Figure 2).

The fifteen stations selected for June, were sampled again on July 27, 28 and 29, 1981. The program was, however, expanded at this time to include five stations in Moberley and Jackfish Bays, three additional stations in the vicinity of the water intake, one station at the water treatment plant and another in Blackbird Creek. These stations are identified alphabetically in Figure 3.

Standard Ministry of the Environment survey techniques were employed for the collection and preservation of all samples. All samples were collected from one metre below the surface, unless otherwise specified in the tables. Samples were packed with ice and shipped each evening to the Ministry's Regional Laboratory in Thunder Bay. Special techniques were employed at the laboratory to isolate and enumerate specific types of bacteria.

RESULTS AND DISCUSSIONS

WATER QUALITY - BACTERIA

Background Information

Raw water samples collected from Kimberly-Clark's pumphouse, have revealed a repeating, seasonal fluctuation in bacteria levels (Tables 1 and 2). Waters virtually free of bacteria during the winter months (total and fecal coliform levels generally <10 col/100 ml) were found to contain an increasing bacterial concentration through spring, reaching a peak in July-August. Highest bacterial levels were recorded in July, 1981, with total coliform, background and fecal coliform levels of 324, 4,400 and 112 col/100 ml respectively (Table 2). Total and fecal

coliform levels of <10 col/100 ml are generally restored by early September and with a few exceptions are maintained through to the following spring.

Occasionally, low levels of bacteria of the total coliform group, have been detected in the treated water at the plant. This, however, has occurred on very few occasions and has not presented a health problem to the consumer.

Water quality monitoring conducted on Creek A, Creek B and the Aguasabon River (Figure 1) during the summer of 1980, revealed concentrations of bacteria which would have little impact on Lake Superior (Table 3). Further, the volumes discharged from the above streams during the summer months were extremely low.

Significantly elevated bacterial activity, in addition to high flows, were recorded for Blackbird Creek. Monthly bacteriological data for 1980 and 1981 are presented in Tables 4 and 5 respectively. During normal operation of the mill, total coliform, fecal coliform and background bacteria levels, generally exceeded 1.0×10^6 col/100 ml. Moreover, flow rates for Blackbird Creek were in excess of 100,000 m^3/day. This volume represents the average daily discharge from the mill.

Bacterial Enumeration and Distribution in Lake Superior

During the period June 23-25, 1981, Water Resources Branch recorded extremely high bacteria levels in Moberley Bay. These high levels were found to disperse rather slowly in the waters of Jackfish Bay (Table 6, Figure 3). A physical and chemical profile through the water column, showed the discharge to be thermally stratified, resulting in limited mixing with the immediate receiving waters.

The current in Lake Superior, serves to maintain a reasonably high concentration of the discharge along the west shore of Jackfish Bay (Table 6). Typically, the discharge continues past Cape Victoria, westward toward Terrace Bay (Tables 7-10). This is best illustrated in Figure 4, which depicts the distribution

of fecal coliforms during this period. On June 25, fecal coliforms as high as 500 col/100 ml were found at a point midway between the Terrace Bay pumphouse and Cape Victoria. The area immediately west of the pumping station was also under the influence of the effluent at this time.

Daily differences in plume delineation (Figure 4), appear to be a function of the weather. A southeast wind of seven knots on June 24 (Table 11), confined the effluent plume to Jackfish Bay, whereas a wind from the east on June 25, appeared to assist the westward flow of the plume.

Evidence suggesting that Kimberly-Clark's effluent was responsible for the bacteria detected at their pumphouse, was even more pronounced during the July 27-29, 1981, sampling period. Fecal coliform levels in excess of one million colonies per 100 ml in Moberley Bay, can be seen to be progressively diluted to just under 500 col/100 ml at Pumphouse Bay (Tables 12, 13 and 14). A similar distribution of _Pseudomonas aeruginosa_ was observed, ranging from greater than a million at the effluent outfall (Station 2b), to greater than 600 col/100 ml east of the pumphouse (Station 9a) (Tables 13 and 14).

Bacterial Isolation and Speciation

The coliform group of micro-organisms has been the most commonly used bacteriological indicator of water quality. The concentration of fecal coliforms in water can be related quantitatively to the presence of sewage or fecal matter in the water (2). Domestic sewage, however, constitutes an extremely small portion of Kimberly-Clark's effluent, and it is treated prior to discharge.

Discharges associated with the pulp industry, include large numbers of the bacteria _Klebsiella pneumoniae_. Although not normally found in large numbers in human wastes, certain species of _Klebsiella_ are intestinal inhabitants of warm-blooded animals and are included in the fecal coliform category. Measurements specific for _Klebsiella_ were conducted on waters collected from

Jackfish Bay, June 23 and 24, 1981. At all stations, the Klebsiella count exceeded that of the fecal coliforms (Table 6) illustrating that in addition to the large numbers, different strains of Klebsiella were present as well. A study conducted by Kanarek and Caplenas (1981), on the effluent of several Wisconsin pulp and paper mills, revealed that of the fecal coliform group of bacteria, as high as 97% belonged to the genus Klebsiella.

Health hazards associated with these bacteria remain in question. Research is currently being conducted to determine if, in fact, bacteria of the genus Klebsiella are disease producing in humans.

Measurements for the bacteria Escherichia coli were also obtained from Jackfish Bay waters. The bacteria E. coli, which comprises the majority of the fecal coliform group in human waste, was not detected in samples from Jackfish Bay (Table 6).

Where bacteria are known to occur in large numbers, representative samples must be proportionately diluted to enable one to distinguish between discrete colonies of the bacteria when cultured. Bacterial counts as those that are known to occur in Kimberly-Clark's effluent, requires that large dilutions of the samples be made. As a result, even though no E. coli were detected, for statistical reasons, counts of less than 100,000 and less than 10,000 are the most accurate the laboratory can report.

Bacterial species are identified by both chemical properties and distinguishing physical features. A visual examination of the cultured bacteria, revealed background colonies with common physical characteristics. These common characteristics were observed in samples collected from Station 3 through 9a. An additional connection between the discharged effluent and the water intake was provided by the bacteria Pseudomonas aeruginosa. Although present in diminishing numbers, two physically identifiable strains of P. aeruginosa were found in similar proportions in the waters collected from the effluent outfall through to Station 8a.

WATER QUALITY - PHYSICAL AND CHEMICAL

Physical

On site measurements of dissolved oxygen (D.O.) and temperature, provided no assistance in delineating the effluent plume. A decrease in D.O. and an increase in temperature were recorded only at Station 2b, immediately below the effluent outfall (Table 15). Little variability was observed among the remaining stations.

Secchi disc transparencies, a measure of light transmission through the water column, showed progressive improvement from the effluent outfall (Station 2b) through to Cape Victoria (Station 3). Light transmission remained impaired as far west as Station 7 on July 28 (Table 15).

Chemical

General water quality parameters showed little deviation from the measured background levels in June (Table 16). Effluent chloride levels, approximately 500 mg/ℓ (Table 17, Appendix 1), resulted in marginally elevated chloride levels extending as far as Station 3. The maximum chloride level recorded at Station 3 was 5.5 mg/ℓ, up somewhat from a background concentration of 1.4 mg/ℓ. A similar increase in sodium levels was also recorded.

Samples collected within Jackfish Bay during July, revealed that any elevated chemical parameters, were essentially restricted to an area less than 2 kilometres from the effluent outfall (Station 2c) (Table 17). Chloride and turbidity were the only measured parameters found to be elevated beyond this area. Chloride and turbidity levels were measureably higher than background concentrations, as far west as Station 5.

Analyses for organic components, conducted on samples collected by Water Resources Branch in June, revealed that the organic constituents from the effluent outfall, were virtually undetectable 1.5 km away. Sample locations and measured concentrations are illustrated in Appendix 2.

CONCLUSIONS

1. There is a pronounced seasonal fluctuation in bacterial levels in the raw water supply for Terrace Bay. This, however, has not presented a health problem to the consumer.
2. The discharge from Blackbird Creek is responsible for the elevated bacterial levels found in Lake Superior in the vicinity of Terrace Bay.
3. The effluent from a pulp mill, owned and operated by Kimberly-Clark of Canada Limited, has been continuously discharging to Blackbird Creek since December, 1948.
4. Bacterial speciation provided a definite link between the bacteria collected at the Blackbird Creek outfall and the bacteria collected from Pumphouse Bay.
5. Water samples revealed elevated bacteria, present in diminishing numbers, from the Blackbird Creek discharge through to the water intake.
6. The fecal coliform group was comprised largely of bacteria from the genus Klebsiella.
7. Of the measured chemical parameters, the organic constituents were virtually non-detectable 1.5 km from the effluent outfall.
8. Elevated inorganic parameters were essentially restricted to an area within 2 km of the effluent outfall.
9. Several small streams discharge to Lake Superior in the vicinity of the water intake, however, only Blackbird Creek contains sufficient bacteria and is of sufficient volume, to have any measurable impact on Lake Superior.

RECOMMENDATIONS

It is recommended that:

1. The current bacterial monitoring programme be maintained.

2. An adequate chlorination capacity remain available.

3. The Ministry of the Environment enforce the Control Order currently in place with Kimberly-Clark, which requires the improved quality of the mill effluent to meet Provincial and Federal regulations.

4. The study presently being undertaken by Kimberly-Clark on the alternatives for alleviating the impact of the effluent on the Blackbird Creek system, should also address the elevated bacterial levels associated with the discharge.

REFERENCES

1. Kanarek, M. S., and N. R. Caplenas. 1981. Epidemiological study of Klebsiella pneumoniae among pulp and paper mill workers. Environmental Protection Agency Publication, EPA-600/S1-81-023.

2. Ontario Ministry of the Environment. 1968. Water Management: Goals, Policies, Objectives and Implementation Procedures of the Ministry of the Environment. O.M.O.E. Pub.

FIGURE 1 TOWNSHIP OF TERRACE BAY
SAMPLING LOCATIONS
JUNE, 1981

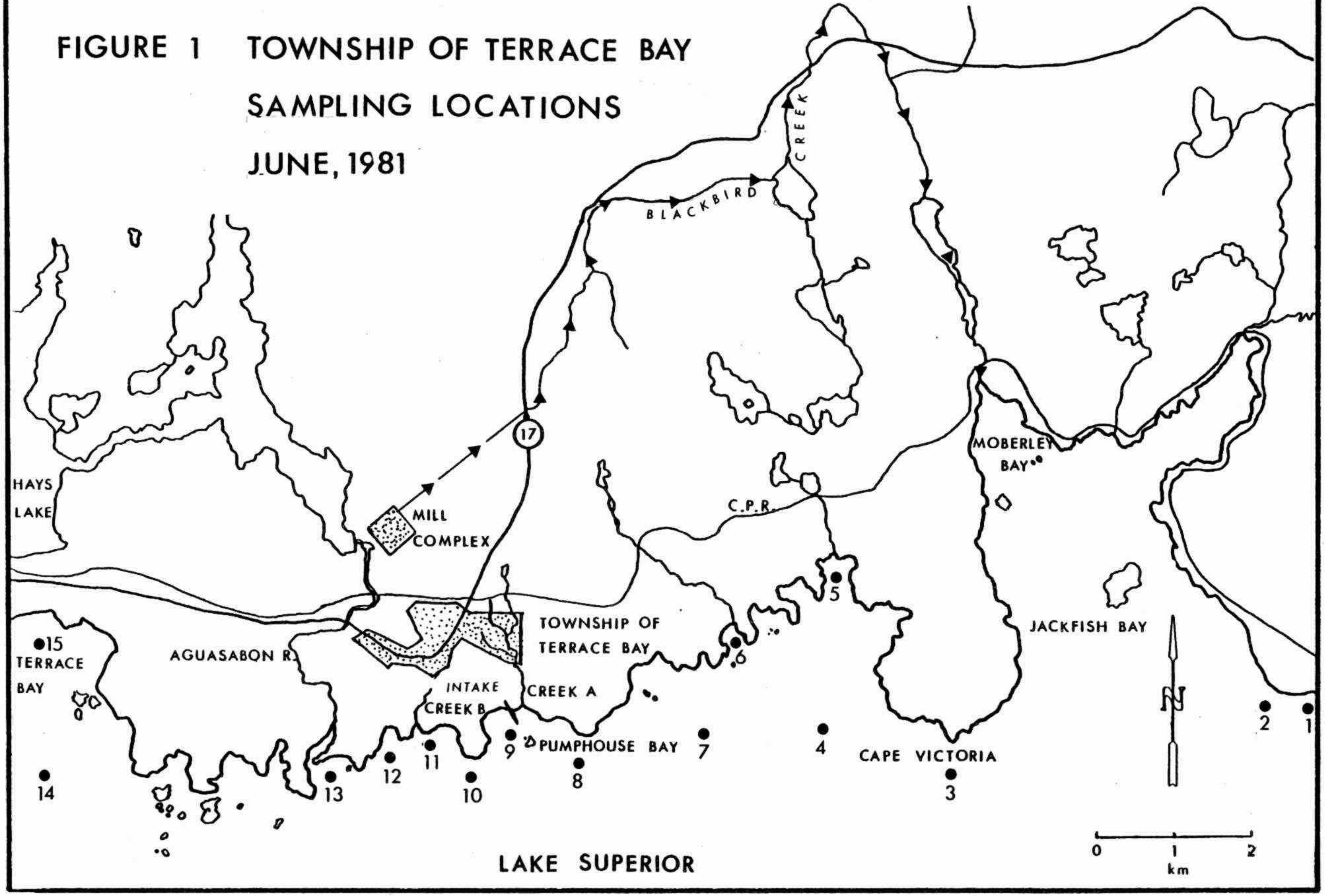

FIGURE 2 WATER RESOURCES BRANCH SURVEY
JACKFISH BAY
JUNE, 1981

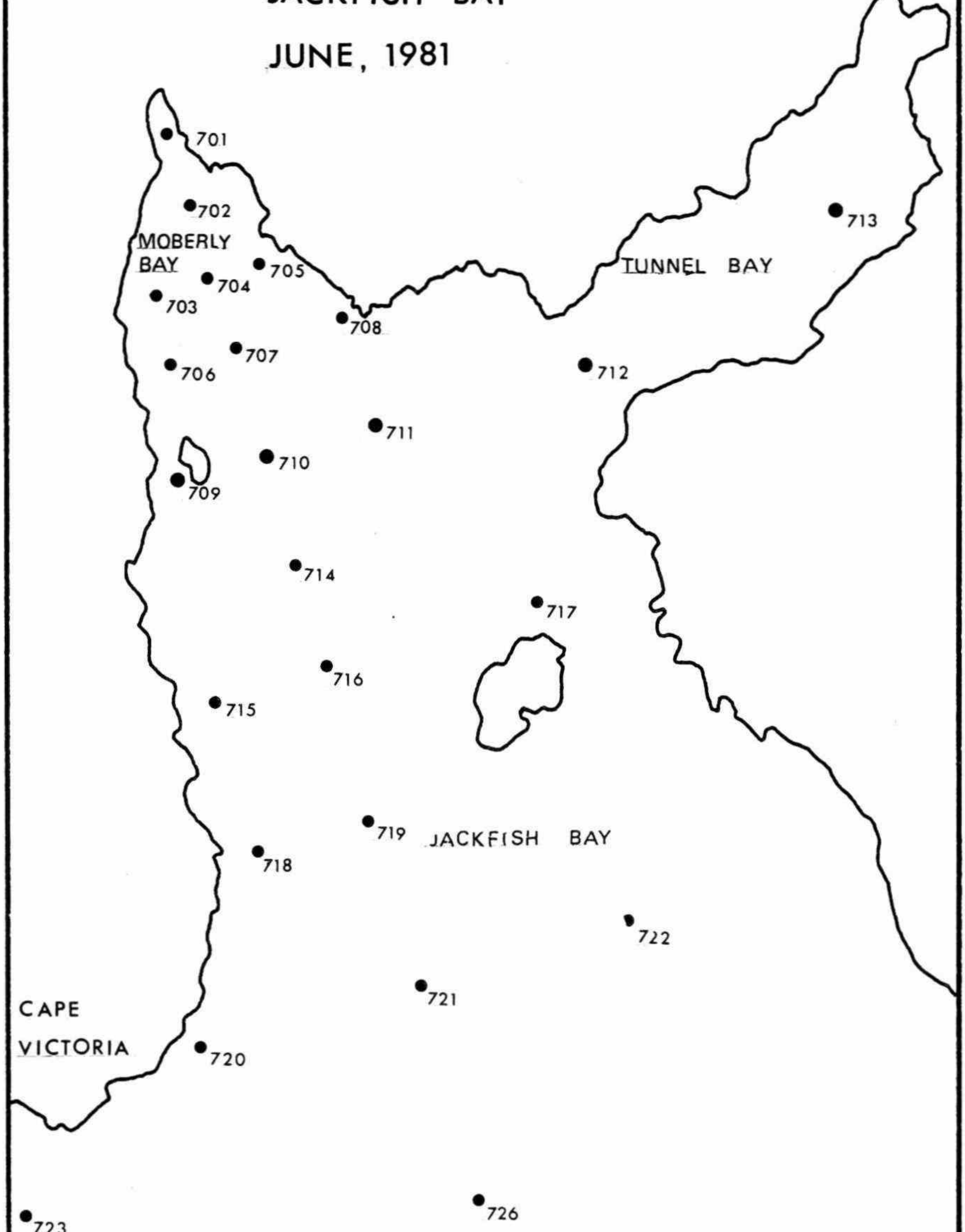

FIGURE 3 TOWNSHIP OF TERRACE BAY
SAMPLING LOCATIONS
JULY, 1981

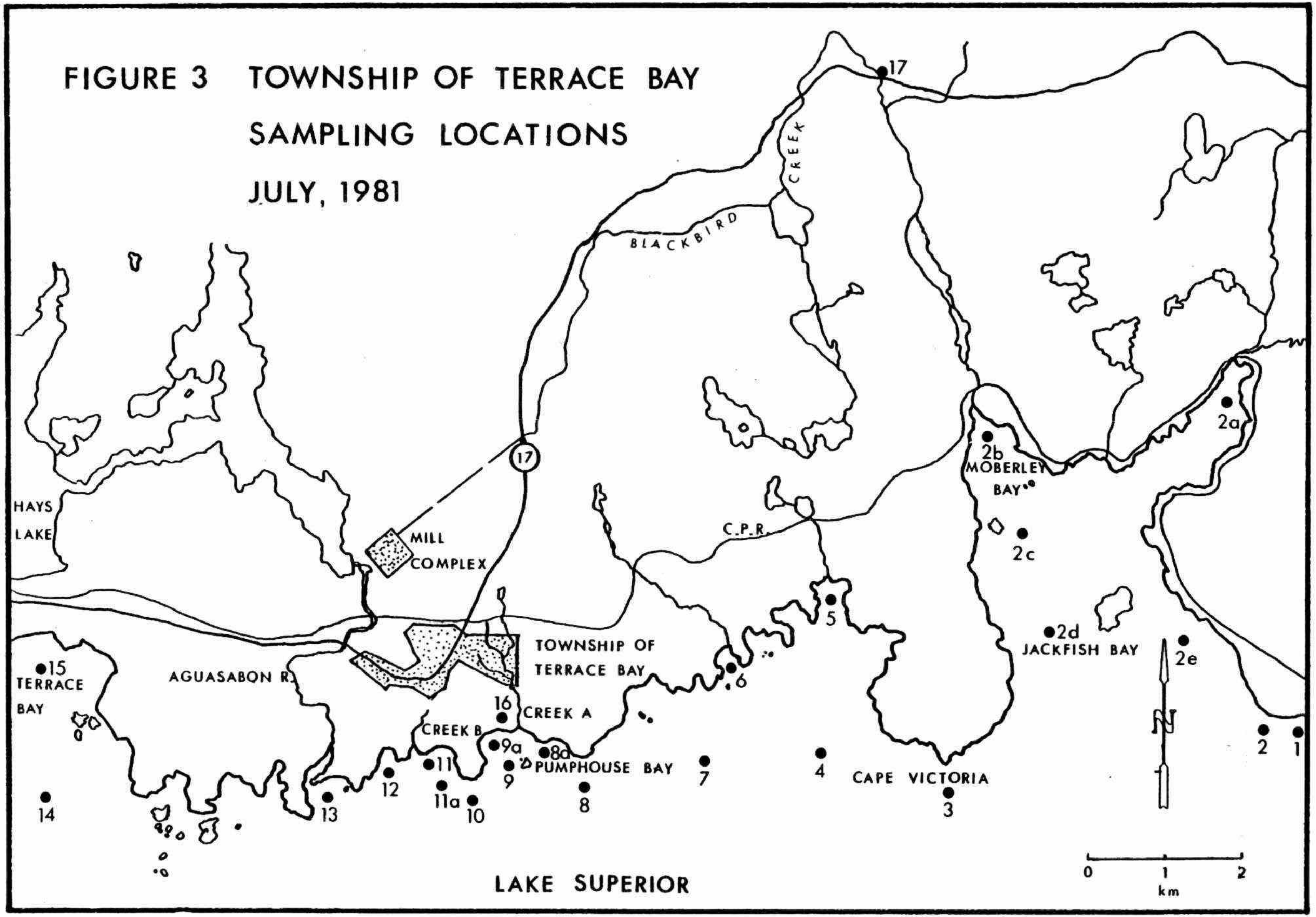

FIGURE 4 DISTRIBUTION OF FECAL COLIFORMS, LAKE SUPERIOR

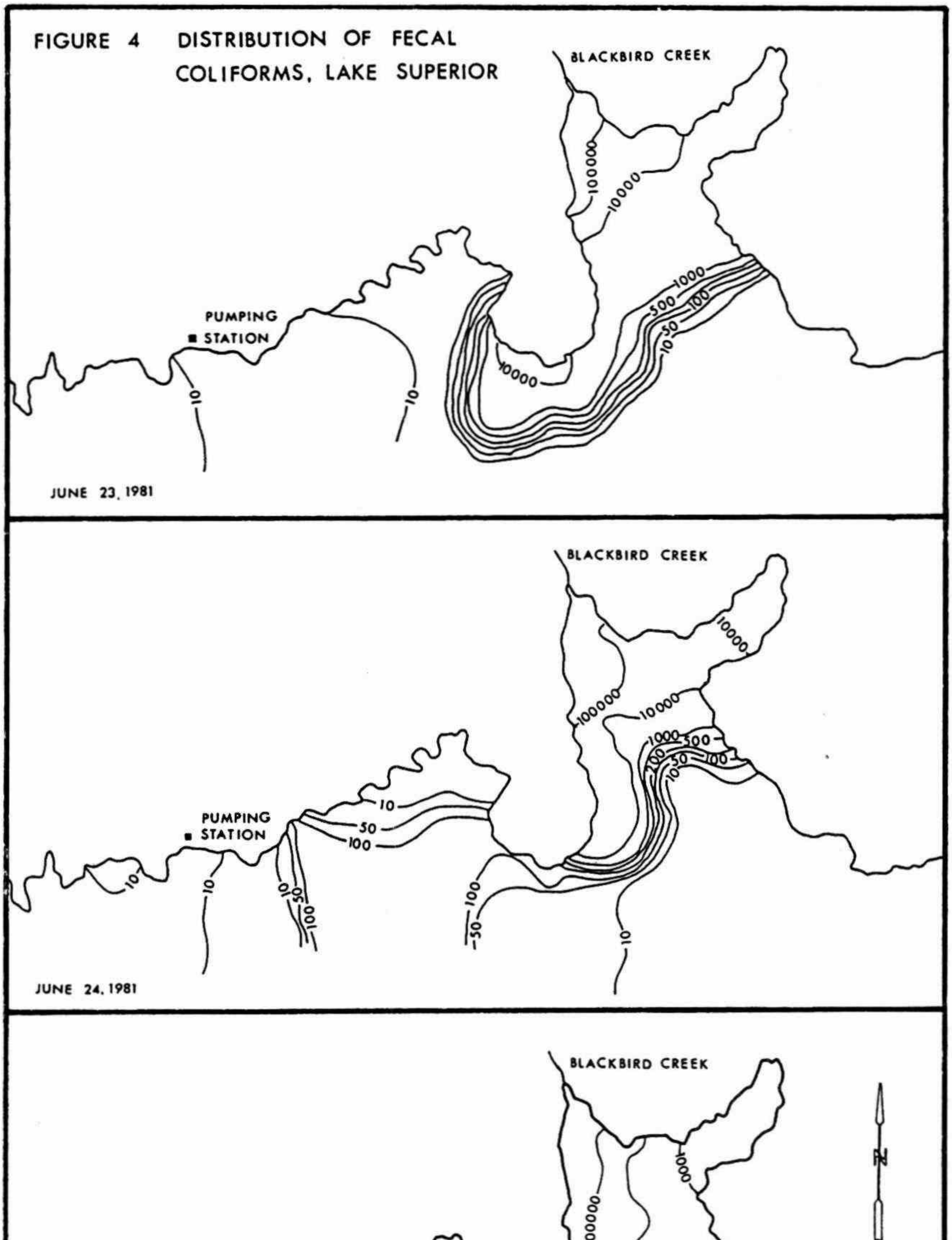

TABLE 1. Bacterial colony counts (/100 ml) in raw water sampled from Kimberly-Clark's pumphouse, Terrace Bay, 1980.

	Total Coliform		Background		Fecal Coliform		Fecal Streptococci	
Date	Raw	Treated	Raw	Treated	Raw	Treated	Raw	Treated
Feb 11	4	-	-	-	2	-	-	-
Feb 18	4	-	-	-	2	-	-	-
Feb 25	0	-	-	-	0	-	-	-
Mar 7	0	-	-	-	0	-	-	-
Mar 10	0	-	-	-	0	-	-	-
Mar 17	0	-	-	-	0	-	-	-
Apr 1	0	-	-	-	0	-	-	-
Apr 8	2	-	-	-	0	-	-	-
Apr 15	0	-	-	-	0	-	-	-
Apr 22	0	-	-	-	0	-	-	-
Apr 28	0	-	-	-	0	-	-	-
May 12	0	-	-	-	0	-	-	-
May 26	16	-	-	-	5	-	-	-
Jun 2	26	-	-	-	10	-	-	-
Jun 9	10	-	-	-	0	-	-	-
Jun 16	0	-	-	-	0	-	-	-
Jun 23	0	-	-	-	0	-	-	-
Jun 30	0	-	-	-	0	-	-	-
Jul 7	15	-	-	-	15	-	-	-
Jul 10	66	-	-	-	66	-	-	-
Jul 14	140	-	-	-	42	-	-	-
Jul 16	54	-	-	-	18	-	-	-
Jul 21	12	-	-	-	9	-	-	-
Jul 23	156	-	-	-	58	-	-	-
Jul 28	11	-	-	-	11	-	-	-
Jul 30	142	-	-	-	60	-	-	-
Aug 5	8	-	-	-	0	-	-	-
Aug 11	160	-	-	-	60	-	-	-
Sep 8	12	-	-	-	1	-	-	-
Sep 9	<10	-	7000	-	<4	-	<4	-
Sep 15	<2	0	<2	-	<2	0	<2	0
Sep 24	<2	0	16	-	<2	0	<2	0
Sep 30	<2	0	8	-	<2	0	<2	0
Oct 6	<4	0	<4	-	<4	0	<4	0
Oct 14	<2	0	<2	-	<2	0	<2	0
Oct 20	<10	0	<10	-	<2	0	<2	0
Oct 27	<2	present	<2	-	<2	0	<2	0

TABLE 1. (Continued).

Date	Total Coliform		Background		Fecal Coliform		Fecal Streptococci	
	Raw	Treated	Raw	Treated	Raw	Treated	Raw	Treated
Nov 3	<2	0	<2	2	<2	0	<2	0
Nov 10	2	present	24	-	<2	present	<2	0
Nov 18	2	0	10	16	<2	0	<2	0
Nov 24	12	10	14	12	<2	present	<2	0
Dec 1	<2	0	<2	2	<2	0	<2	0
Dec 8	<2	present	10	-	<2	present	<4	0
Dec 16	<2	present	<2	<2	<2	0	<2	0
Dec 22	<2	0	<2	0	<2	0	-	0
Dec 29	<2	0	<2	-	<2	0	-	0

TABLE 2. Bacterial colony counts (/100 ml) in raw water sampled from Kimberly-Clark's pumphouse, Terrace Bay, 1981.

Date	Total Coliform		Background		Fecal Coliform		Fecal Streptococci		Pseudomonas aeruginosa	
	Raw	Treated	Raw	Treated	Raw	Treated	Raw	Treated	Raw	Treated
Jan 7	<2	0	<2	-	<2	0	<2	0	-	0
Jan 13	<2	-	<2	-	<2	-	<2	-	-	-
Jan 19	<2	present	<2	-	<2	0	<2	0	-	0
Jan 26	<2	0	2	<2	<2	0	<2	0	-	present
Feb 2	36	present	400	-	6	0	-	0	-	0
Feb 9	4	0	140	<2	<2	0	<2	0	-	0
Feb 16	<2	0	12	-	<2	0	<4	0	-	0
Feb 23	<2	0	12	-	<2	0	10	0	-	0
Mar 2	<2	0	<2	-	<2	0	<2	0	-	0
Mar 9	<2	0	6	-	<2	0	<2	0	-	0
Mar 16	16	0	44	-	<2	0	<2	0	-	0
Mar 23	<4	0	24	-	<2	0	<2	0	-	0
Mar 30	8	0	26	-	2	0	<2	0	-	0
Apr 6	82	present	400	-	24	0	<2	0	-	0
Apr 8	A28	0	740	<2	A10	0	<2	0	-	0
Apr 13	22	present	110	<2	<2	0	<10	0	-	0
Apr 20	4	0	262	-	6	0	<2	0	-	0
May 4	6	0	460	-	2	0	<2	0	-	0
May 11	24	0	400	-	20	0	<2	0	-	0
May 20	48	0	76	-	4	0	<2	0	-	0
May 25	50	0	400	-	12	0	2	0	-	0
May 27	A26	0	2400	-	6	0	<2	0	-	0

TABLE 2. (Continued).

Date	Total Coliform Raw	Total Coliform Treated	Background Raw	Background Treated	Fecal Coliform Raw	Fecal Coliform Treated	Fecal Streptococci Raw	Fecal Streptococci Treated	*Pseudomonas aeruginosa* Raw	*Pseudomonas aeruginosa* Treated
Jun 1	2	0	10	-	2	0	<2	0	-	0
Jun 8	A18	0	940	-	A8	0	8	0	-	0
Jun 15	86	0	442	<2	44	0	68	0	-	0
Jun 30	A86	present	800	-	32	0	<2	0	-	present
Jul 6	A324	0	4400	-	112	0	<2	0	-	0
Jul 13	130	0	1480	<4	48	0	<4	0	present	0
Jul 20	180	-	410	-	28	-	<4	-	57	-
Jul 27	280	-	2100	-	32	-	<4	-	151	-
Aug 5	110	0	530	<2	4	0	<4	0	28	0
Aug 10	A30	0	200	-	12	0	<4	0	9	0
Aug 17	130	0	1810	-	48	0	8	0	84	0
Aug 19	A80	0	1410	-	<4	0	<4	0	32	0
Aug 24	A40	0	5000	-	A28	0	<4	0	16	0
Aug 26	A20	0	350	-	<4	0	<4	0	<1	0
Aug 31	<10	0	<10	-	<4	0	<4	0	1	0
Sep 2	<10	0	A70	-	<4	0	<4	0	<2	0
Sep 9	-	-	-	-	-	-	-	-	-	-
Sep 14	A20	0	A30	-	<4	0	<4	0	-	0
Sep 16	<10	0	<10	-	<4	0	<4	0	<1	0
Sep 21	<10	0	<10	-	<4	0	<4	0	<1	0
Sep 23	<10	0	A10	-	<4	0	4	0	-	0
Sep 28	<10	0	A80	-	<2	0	<2	0	<2	0
Sep 30	<10	0	A30	-	<4	0	<2	0	<2	0

TABLE 2. (Continued).

Date	Total Coliform		Background		Fecal Coliform		Fecal Streptococci		Pseudomonas aeruginosa	
	Raw	Treated	Raw	Treated	Raw	Treated	Raw	Treated	Raw	Treated
Oct 5	A20	0	A30	-	<4	0	<4	0	<1	0
Oct 7	A20	0	230	-	<4	0	<4	0	-	0
Oct 13	<10	0	<10	-	<4	0	<4	0	-	0
Oct 19	<10	0	A10	-	8	0	<4	0	<1	0
Oct 26	>1500	0	>10000	-	32	0	<10	0	-	0
Nov 2	A40	0	500	-	4	0	<4	0	<1	0
Nov 9	<10	0	<10	-	<4	0	<4	0	<1	0
Nov 16	A10	0	<10	-	<4	0	<4	0	<1	0
Nov 23	<10	0	<10	-	<4	0	<4	0	<1	0
Nov 30	<10	0	<10	-	<4	0	<4	0	<1	0
Dec 7	<10	0	<10	-	<4	0	<4	0	<1	0
Dec 14	<10	0	<10	-	<4	0	<4	0	<2	0
Dec 21	<10	<2	<10	<2	<4	<2	<4	<2	<1	-
Dec 29	<10	0	<10	-	<4	0	<4	0	<1	0

Note: A - Approximately.
< - Less than.
> - Greater than.

TABLE 3. Bacterial colony counts (/100 ml) in three separate discharges to Lake Superior, September 9, 1980.

Location	Total Coliform	Background	Fecal Coliform	Fecal Streptococci
1. West branch Creek A	A1900	3.1×10^4	520	1280
2. East branch Creek A	A300	1.0×10^4	A20	130
3. Mouth of Creek A	900	2.5×10^4	170	650
4. Lake Superior, west of Creek A, 45 m offshore	<10	160	<4	4
5. Creek B, adjacent to lagoon	A250	5300	16	60
6. Creek B, downstream of lagoon	A400	5700	A30	10
7. Mouth of Creek B	A700	1.1×10^4	12	32
8. Aguasabon River downstream Highway #17	A210	5900	32	56
9. Mouth of Aguasabon River	110	1560	24	36

Note: Data presented in this table were generated from the 1980 survey.
A = Approximately.
< = Less than.

TABLE 4. Bacterial colony counts (/100 ml) in waters sampled from Blackbird Creek, January to November, 1980.

Date	Total Coliform	Fecal Coliform	Fecal Streptococci	Background
Jan 8	A6.6 x 10^6	6.5 x 10^6	150	2.3 x 10^7
Jan 29	3.9 x 10^6	1.5 x 10^6	1800	1.2 x 10^7
Feb 26	A270*	A30*	390*	1.4 x 10^4
Mar 17	3.30 x 10^7	1.08 x 10^7	6800	1.2 x 10^8
Apr 29	--	4.0 x 10^6	--	--
May 26	<10*	<10*	--	<10
Jun 23	A7.0 x 10^4	A4.0 x 10^3	--	4.0 x 10^6
Jul 29	7.80 x 10^7	5.80 x 10^7	--	6.5 x 10^7
Aug 25	2.50 x 10^7	1.20 x 10^7	--	1.2 x 10^8
Sep 29	A6.0 x 10^5	A2.0 x 10^5	--	5.2 x 10^6
Oct 27	A2.60 x 10^8	2.30 x 10^7	--	6.0 x 10^9
Nov 24	2.60 x 10^7	1.20 x 10^7	--	7.1 x 10^7

Note: Data presented in this table were obtained from the Technical Support Section.

*Mill shut down.

A = Approximately.

TABLE 5. Bacterial colony counts (/100 ml) in water sampled from Blackbird Creek, January to November, 1981.

Date	Total Coliform	Fecal Coliform	Background	Pseudomonas aeruginosa
Jan 6	2.40×10^7	A5.0×10^5	1.70×10^8	--
Jan 27	$<1.0 \times 10^3$	<100	2.0×10^5	--
Feb 23	A5.5×10^6	1.7×10^6	4.0×10^7	--
Mar 23	1.8×10^8	7.0×10^7	2.7×10^8	--
Apr 27	A4.0×10^5	1.2×10^5	1.6×10^6	--
May 26*	<100*	A10*	A800*	--
Jun 29*	<10*	--	<10*	<100*
Jul 27	$>1.5 \times 10^8$	$>1.5 \times 10^7$	8.0×10^8	--
Aug 24	$<1.0 \times 10^4$	$<1.0 \times 10^3$	4.0×10^7	<100
Sep 28	2.6×10^7	A8.0×10^6	3.8×10^7	3.6×10^5
Oct 27	2.4×10^5	4.9×10^4	4.3×10^5	<100
Nov 25	<100*	<10*	7.0×10^4	--

Note: Data presented in this table were obtained from the Technical Support Section.

*Mill shut down.

A = Approximately.

< = Less than.

> = Greater than.

TABLE 6. Bacterial colony counts (/100 ml) from Jackfish Bay, Lake Superior, June, 1981.

Station	Date	Pseudomonas aeruginosa	Fecal Coliform	Klebsiella sp.	Escherichia coli
701	23	8,100	2,100,000	3,800,000	-
	24	19,000	600,000	1,300,000	<100,000
	25	-	1,300,000	A4,000,000	-
702	23	-	A800,000	A1,900,000	-
	24	-	300,000	1,200,000	<10,000
	25	-	280,000	300,000	-
703	24	-	480,000	-	<10,000
704	23	15,000	170,000	-	-
	24	11,100	310,000	-	-
	25	8,500	350,000	-	-
705	23	-	54,000	>100,000	-
706	24	-	A700,000	-	<100,000
707	23	-	15,000	-	-
	24	-	1,200,000	-	<100,000
	25	-	120,000	-	-
709	23	-	150,000	270,000	-
710	23	300	15,000	-	-
	24	600	120,000	-	-
	25	1,500	58,000	-	-
714	23	-	1,500	-	-
	24	-	1,000	-	-
	25	-	50,000	-	-
716	23	-	1,500	-	-
	24	-	6,000	-	-
	25	-	1,300	-	-

TABLE 6. (Continued).

Station	Date	*Pseudomonas aeruginosa*	Fecal Coliform	*Klebsiella sp.*	*Escherichia coli*
717	23	-	4,700	A8,900	-
718	24	-	A90,000	150,000	-
	25	-	85,000	120,000	-
719	23	-	1,500	-	-
	24	-	340	-	-
	25	-	400	-	-
721	23	-	20	-	-
	24	-	10	-	-
	25	-	10	-	-
722	23	-	A10	<10	-

Note: Data presented in this table were generated from samples collected by Water Resources Branch, Toronto. See Figure 3 for station locations.

TABLE 7. Bacterial colony counts (/100 ml) from 15 locations on Lake Superior, June 22, 1981.

Station	Total Coliform	Background	Fecal Coliform	*Escherichia coli*	Heterotroph
1	<10	<10	<10	--	--
2	<10	<10	A10	--	A8.0 x 10^2
3	110,000	410,000	19,000	--	A7.0 x 10^4
4	570	1,700	100	--	1.1 x 10^4
5	<10	<10	<10	--	--
6	<10	A10	<10	--	--
7	A60	A80	A20	--	3.5 x 10^3
8	100	670	A50	--	1.7 x 10^4
9	A40	360	A60	--	3.5 x 10^3
10	A20	A20	A20	--	--
11	A10	A70	A10	--	--
12	A10	120	<10	--	--
13	A40	280	A10	--	--
14	A10	190	A20	--	--
15	A20	A60	<10	--	--

Note: A = Approximately.

< = Less than.

TABLE 8. Bacterial colony counts (/100 ml) from 15 locations on Lake Superior, June 23, 1981.

Station	Total Coliform	Background	Fecal Coliform	*Escherichia coli*	Heterotroph
1	<10	180	<4	--	--
2	A10	A60	4	--	3.5×10^2
3	>15,000	>100,000	>15,000	--	1.1×10^5
4	A20	100	8	--	3.0×10^2
5	<10	<10	4	--	--
6	A20	A30	<4	--	--
7	A70	180	20	--	2.8×10^3
8	A20	A40	28	--	3.6×10^3
9	<10	50	12	--	6.7×10^3
10	<10	<10	4	--	--
11	<10	<10	<4	--	--
12	<10	<10	<4	--	--
13	<10	A20	8	--	--
14	<10	A50	4	--	--
15	A10	A70	<4	--	--

A = Approximately.
< = Less than.
> = Greater than.

TABLE 9. Bacterial colony counts (/100 ml) from 15 locations on Lake Superior, June 24, 1981.

Station	Total Coliform	Background	Fecal Coliform	*Escherichia coli*	Heterotroph
1	<10	A50	<4	--	--
2	<10	A90	<4	--	A1.0 x 10^3
3	A400	2,300	A100	--	A3.0 x 10^3
4	A550	5,100	112	--	2.8 x 10^3
5	<10	A20	<4	--	--
6	A10	A80	<4	--	--
7	A590	3,000	124	--	2.1 x 10^3
8	A20	110	<4	--	5.2 x 10^3
9	A20	A70	16	--	8.0 x 10^3
10	100	340	24	--	--
11	A20	A30	4	--	--
12	A50	100	12	--	--
13	<10	A90	12	--	--
14	<10	A40	<4	--	--
15	A10	120	4	--	--

A = Approximately.
< = Less than.

TABLE 10. Bacterial colony counts (/100 ml) from 15 locations on Lake Superior, June 25, 1981.

Station	Total Coliform	Background	Fecal Coliform	*Escherichia coli*	Heterotroph
1	A20	140	<4	--	--
2	<10	A70	<4	--	<100
3	49,000	230,000	A4,000	--	2.2×10^4
4	3,300	18,700	>600	--	--
5	A20	140	20	--	--
6	A40	230	24	--	--
7	520	2,140	96	--	2.5×10^3
8	330	710	80	--	3.2×10^3
9	140	330	68	<4	5.0×10^3
10	280	470	40	<4	--
11	A60	170	24	--	--
12	110	520	44	--	--
13	100	330	12	--	--
14	A10	A50	24	--	--
15	<10	110	<4	--	--

A = Approximately.
< = Less than.
> = Greater than.

TABLE 11. Climatological data for the Terrace Bay area, June 22-25 and July 27-29, 1981.

Date	Average Wind Direction (degrees)	Wind Speed (knots)
June 22	050*	8.0
23	-	-
24	150	7.0
25	070	7.0
July 27	230	8.0
28	-	-
29	130	Calm

*Where: North = 0°, East = 90°, South = 180° and West = 270°.

TABLE 12. Bacterial colony counts (/100 ml) from 25 locations on Lake Superior, July 27, 1981.

Station	Total Coliform	Background	Fecal Coliform	Fecal Streptococci	*Pseudomonas aeruginosa*
1	<10	150	<4	--	--
2	<10	10	<4	--	--
2a	A120	4500	A30	--	--
2b	2,600,000	20,000,000	2,300,000	A700	--
2c	A48,000	500,000	15,000	--	--
2d	A60,000	700,000	13,000	--	--
2e	19,000	270,000	A7,000	--	--
3	A8,000	60,000	1,000	<10	--
4	2,200	29,000	A600	--	--
5	35,000	200,000	A6,000	--	--
6	A7,000	50,000	1,200	--	--
7	A300	6,000	140	--	--
8	<10	310	<10	--	--
8a	A30	1,100	A10	--	--
9	<10	A20	<10	--	--
9a	<10	A70	<10	--	--
10	<10	A20	<4	--	--
11	A10	A40	<4	<4	--
11a	<10	<10	<4	--	--
12	<10	<10	<4	<4	--
13	<10	A30	<4	<4	--
14	<10	150	<4	--	--
15	<10	A70	<4	<4	--
16	<10	A70	<4	<4	--
17	A85,000,000	410,000,000	>15,000,000	<100	--

A = Approximately.
< = Less than.
> = Greater than.

TABLE 13. Bacterial colony counts (/100 ml) from 25 locations on Lake Superior, July 28, 1981.

Station	Total Coliform	Background	Fecal Coliform	Fecal Streptococci	*Pseudomonas aeruginosa*
1	<10	--	<4	--	<2
2	A1,060	3,000	A116	--	>300
2a	A20	300	<10	<4	16
2b	A6,000,000	70,000,000	1,500,000	1,800	6,700,000
2c	>150,000	>1,000,000	G150,000	--	>15,000
2d	25,000	200,000	A3,000	--	>1,500
2e	32,000	180,000	A6,000	--	>15,000
3	2,000	12,000	A300	<10	A900
4	<10	<10	<10	--	<10
5	>15,000	70,000	A3,800	--	>1,500
6	A13,000	49,000	A800	<10	>1,500
7	>1,500	>10,000	G1,500	--	>600
8	A420	4,700	A20	--	452
8a	>1,500	6,000	A460	--	>600
9	<10	320	<10	<10	20
9a	>1,500	8,000	A440	--	>600
10	A10	700	16	--	34
11	A20	120	<4	<4	4
11a	A10	280	16	--	16
12	<10	A60	<4	<4	<2
13	<10	540	<4	<4	18
14	<10	A80	4	--	14
15	A10	150	<4	<4	8
16	<10	A70	A10	<4	12
17	A3,000,000	270,000,000	A200,000	A200	A800,000

A = Approximately.
< = Less than.
> = Greater than.

TABLE 14. Bacterial colony counts (/100 ml) from 25 locations on Lake Superior, July 29, 1981.

Station	Total Coliform	Background	Fecal Coliform	Fecal Streptococci	*Pseudomonas aeruginosa*
1	A10	400	4	--	<2
2	>1,500	6,000	>600	--	>300
2a	>1,500	7,500	A410	<4	>300
2b	A7,000,000	60,000,000	1,800,000	2,700	>1,500,000
2c	A490,000	4,300,000	120,000	--	>150,000
2d	A470,000	4,400,000	130,000	--	54,000
2e	A8,000	50,000	1,100	--	7,400
3	1,500	10,000	A800	<10	2,700
4	7,500	17,000	1,500	--	>600
5	5,700	20,000	1,300	--	>1,500
6	4,500	21,000	A900	--	7,900
7	4,000	14,000	A200	--	7,500
8	1,700	5,000	A340	--	2,000
8a	1,200	9,000	A700	--	2,800
9	120	1,500	A10	<4	260
9a	1,000	14,000	A200	<4	>600
10	A10	A80	4	--	28
11	A10	A30	<4	<4	2
11a	<10	A30	4	<4	22
12	A10	A10	<4	--	6
13	A10	A10	<4	<4	<2
14	<10	A20	8	--	2
15	A10	A50	8	<4	<2
16	<10	<10	<4	<4	<4
17	A200,000	4,200,000	330,000	<100	1,100,000

A = Approximately.
< = Less than.
> = Greater than.

TABLE 15. On site measurements, collected from Lake Superior, June 23, 25 and July 27-29, 1981.

	June 23			June 25			July 27			July 28			July 29		
Location	Secchi disc	Temp.	D.O.	Secchi disc	Temp.	D.O.	Secchi disc	Temp.	D.O.	Secchi disc	Temp.	D.O.	Secchi disc	Temp.	D.O.
1	13.0	3.0	12.6	7.0	4.5	10.3	12.0	12.8	-	8.0	11.0	11.4	7.5	11.0	11.2
2	13.5	-	12.8	8.0	4.0	9.3	12.0	10.0	-	8.0	10.5	11.6	6.5	11.0	11.0
2a	-	-	-	-	-	-	11.0	9.0	12.3	8.0	11.0	11.2	8.5	11.5	10.6
2b	-	-	-	-	-	-	0.25	15.0	9.8	<0.1	19.0	5.4	<0.1	13.5	8.5
2c	-	-	-	-	-	-	2.0	12.5	10.8	2.0	12.0	9.6	1.0	12.5	9.4
2d	-	-	-	-	-	-	2.5	11.2	11.2	3.5	11.0	10.4	1.0	13.5	9.2
2e	-	-	-	-	-	-	8.0	11.3	12.0	7.0	10.3	11.6	6.5	11.0	10.6
3	4.2	6.5	12.4	6.0	5.5	9.3	6.0	12.2	11.4	6.5	10.0	11.4	6.5	11.0	10.6
4	13.0	3.5	14.4	12.0	3.5	9.5	6.5	11.5	11.4	8.5	9.5	11.5	6.0	11.0	10.4
5	8.0B	5.25	12.6	10.0B	4.5	9.8	4.0	12.2	11.2	5.3	10.0	10.2	5.0	10.5	10.2
6	6.0B	5.75	12.0	10.0B	4.5	9.5	4.0	12.5	11.2	4.5	11.0	10.0	5.0	11.0	10.2
7	13.0	3.75	13.4	13.0	4.0	10.1	10.0	10.5	12.0	4.0	11.0	10.4	6.0	10.5	10.6
8	13.0	4.00	13.4	>13.0	4.0	9.8	10.0	9.5	12.2	7.5	10.3	10.8	6.5	10.3	10.8
8a	-	-	-	-	-	-	6.0B	10.5	11.8	7.5	10.0	10.8	7.5	10.0	10.8
9	12.0B	4.0	13.6	>13.0	4.0	9.4	10.0	11.2	11.8	9.0	10.0	11.2	8.0	9.3	10.2
9a	-	-	-	-	-	-	5.0B	11.2	11.8	3.5B	10.5	10.0	4.5B	9.0	10.2
10	9.0B	4.25	13.1	13.0	4.0	10.2	10.0	11.0	12.2	8.5	10.5	10.4	8.5	10.0	10.8
11	9.5B	4.5	12.8	13.0	4.5	10.1	3.5B	12.3	12.2	3.0B	10.3	10.6	3.5B	10.0	10.6
11a	-	-	-	-	-	-	3.0B	12.5	11.6	5.0B	10.0	9.6	3.0B	9.8	10.6
12	10.0B	5.0	13.4	13.0	4.0	9.8	9.0B	10.5	12.0	4.0B	10.3	10.4	5.5	10.0	10.2
13	6.0B	5.0	13.0	13.0	4.0	9.6	9.0	10.5	12.2	6.0B	11.0	9.8	8.0B	9.5	10.2
14	8.5	7.0	12.4	10.0	5.5	9.6	8.5	10.3	11.8	8.5	10.5	10.2	8.5	11.0	10.4
15	8.0	9.0	12.0	8.0	7.5	9.0	6.0	11.5	12.2	6.0	12.5	9.8	7.5	13.0	9.6
16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17	-	-	-	-	-	-	-	31.0	3.1	-	27.0	4.2	-	-	-

Note: B - Bottom.

TABLE 16. Concentration of selected water quality parameters in water sampled from Lake Superior, June 23, 24 and 25, 1981.

Station	Date	Hard.	Alk.	Cond.	SO_4	pH	Free NH_3	T.K.N.	NO_3	NO_4	Total P.	D.R.P.	Cl	Na	K	Colour	Turb.	Ca	Mg	BOD
2	23	45	42	118	3.9	7.6	.01	.16	.001	.24	.003	.002	1.1	1.2	.55	22	.30	14	2	--
2	24	43	42	100	3.9	7.4	.01	.17	.001	.29	.003	--	1.3	1.3	.51	196	.25	14	2	0.6
2	25	42	42	102	3.8	6.8	<.01	.20	.002	.27	.008	--	1.2	1.3	.55	18	.60	14	2	0.6
3	23	43	42	123	3.9	7.4	<.01	.12	.004	.27	.004	.002	5.5	4.5	.51	22	.45	14	2	--
3	24	43	41	101	3.6	7.5	<.01	.13	.001	.30	.002	--	1.4	1.4	.49	134	.20	13	3	0.4
3	25	44	41	112	3.9	7.6	<.01	.20	.002	.28	.008	--	4.3	3.6	.55	23	.40	14	2	0.5
5	23	42	41	104	3.6	7.4	.01	.09	.001	.30	.002	.002	1.4	1.5	.47	4	.20	14	2	--
5	24	42	41	100	3.6	7.5	.01	.01	.001	.30	.002	--	1.4	1.4	.47	80	.20	14	2	0.4
5	25	42	41	100	2.8	7.6	<.01	.10	.001	.30	.001	--	1.4	1.5	.47	9	.25	14	2	0.4
9	23	42	41	105	3.0	7.7	<.01	.14	.001	.30	.002	.002	1.4	1.6	.49	4	.20	10	4	--
9	24	43	45	102	3.6	7.5	<.01	.12	.001	.30	.002	--	1.5	1.4	.49	120	.20	13	3	0.6
9	25	41	42	103	2.8	7.7	<.01	.10	.001	.30	.002	--	1.4	1.7	.46	19	.30	14	1	0.1
14	23	46	44	104	3.6	7.6	.01	.20	.001	.24	.004	.003	1.2	1.3	.52	16	2.8	14	3	--
14	24	45	43	104	3.2	7.5	<.01	.17	.002	.25	.003	--	1.2	1.2	.47	85	.25	15	2	0.6
14	25	43	43	104	2.8	7.7	<.01	.13	.001	.28	.002	--	1.3	1.6	.49	15	.30	14	2	1.6

TABLE 17. Concentration of selected water quality parameters in waters sampled from Lake Superior, July 27, 28 and 29, 1981.

Station	Date	Cond.	Free NH_3	T.K.N.	NO_3	NO_4	Total P	D.R.P.	Cl	Turb.	BOD
2	27	104	.01	.11	.002	.28	.004	.003	1.3	.30	0.7
2	28	106	.01	.19	.002	.24	.003	.003	1.2	.40	0.7
2	29	108	<.01	.16	.002	.27	.003	.003	2.9	.35	0.6
2a	27	106	<.01	.11	.001	.28	.004	.003	2.1	.35	0.6
2a	28	107	.02	.15	.002	.27	.003	.003	2.2	.45	0.5
2a	29	110	.01	.14	.002	.27	.003	.003	3.2	.45	0.4
2b	27	620	.04	.75	.021	-	.080	.033	136	2.3	30
2b	28	1500	.06	1.9	.064	-	.21	.080	365	2.4	85
2b	29	1320	.05	.32	.056	-	.18	.074	255	3.1	80
2c	27	136	<.01	.17	.006	.23	.007	.004	8.8	.75	1.2
2c	28	143	<.01	.22	.007	.23	.007	.005	10	.80	1.8
2c	29	245	<.01	.34	.009	.19	.011	.011	35	1.7	6.2
3	27	113	.01	.15	.003	.26	.005	.002	3.8	.50	0.7
3	28	108	.01	.15	.002	.28	.003	.003	2.5	.35	0.6
3	29	109	.01	.17	.002	.28	.009	.004	2.9	.35	0.3
5	27	125	<.01	.15	.004	.25	.006	.003	6.5	.55	0.2
5	28	118	.01	.16	.003	.27	.004	.003	5.1	.45	0.7
5	29	114	<.01	.14	.003	.27	.006	.003	4.2	1.7	0.4
9	27	104	<.01	.10	.002	.28	.002	.003	1.5	.30	0.3
9	28	104	.01	.13	.001	.29	.002	.003	1.6	.30	0.4
9	29	104	<.01	.12	.001	.29	.004	.003	1.7	.35	0.1
14	27	106	.03	.13	.002	.26	.003	.003	1.5	.30	0.4
14	28	102	<.01	.13	.001	.28	.004	.002	1.6	.30	0.4
14	29	109	<.01	.16	.001	.22	.004	.004	1.4	.35	0.2
16	27	103	.01	.12	.001	.29	.005	.003	2.6	.35	0.2
16	28	107	.01	.14	.001	.28	.004	.003	2.8	.35	0.4
16	29	103	.01	.11	<.001	.29	.003	.004	2.4	.45	0.1
17	27	1750	.26	1.6	.069	-	.32	.082	445	23	160
17	28	1320	.04	.95	.035	-	.24	.04	188	25	90
17	29	2200	.27	1.9	.105	.001	.39	.115	545	3.9	220

APPENDIX 1. Concentration of selected parameters sampled from Blackbird Creek at the first and last crossings of Highway #17, 1981.

Date	Parameters	Effluent #1	Effluent #2
April 24	Bacti - Fecal coliform (col/100 ml)	A5.0 x 10^6	A5.0 x 10^6
April 24	- Heterotrophs (col/100 ml)	A2.5 x 10^6	A2.5 x 10^6
April 24	Physical - Colour	1168	1185
April 24	- Turbidity	12	10
April 24	- Conductivity	2100	1600
April 24	- Total solids	1890	1390
April 24	- Suspended solids	160	80
April 24	- Dissolved solids	1730	1310
April 24	Chemical - Arsenic	.008	.003
April 24	- Cadmium	.002	.002
April 24	- Chromium	.045	.027
April 24	- Copper	.025	.012
April 24	- Lead	.027	.021
April 24	- Nickel	.010	.004
April 24	- Zinc	.081	.066
April 24	- BOD_5	240	190
April 24	- COD	1070	775
April 24	- Tannins and Lignans	150	50
April 24	- DOC	320	200
April 24	- Cyanide	N.D.	N.D.
April 24	- pH	6.7	6.5
April 24	- Chloride	627	481
April 24	- Sulphate	34.5	44.3
April 24	- Phathalates	N.D.	N.D.
April 24	- Vanilline	102	46
April 24	- Acetovanilline	51	38
April 24	- Gyaiacol	252	174
April 24	- Phenol	53	53
April 24	- Chlorophorm (μg/ℓ)	69.5	81.9
May 14	- PCB (μg/ℓ)	-	.08
May 14	- HCB (μg/ℓ)	-	.01

Note: All analyses expressed as mg/ℓ unless otherwise indicated.

APPENDIX 2. Concentration of selected organic compounds sampled from Jackfish Bay, Lake Superior, June 23, 1981.

Station	PCB (ppt)	2,4,6,-TRI Chlorophenol (ppt)	2,3,5,6,-Tetra Chlorophenol (ppt)	Pentachloro-phenol (ppt)	Homovanillic acid (ppb)	Vanilline (ppb)	Gyaiacol (ppb)	B-BHC (ppt)
701 0.03 km[1]	26	3300	600	540	-	-	-	12
702 0.36 km	ND	-	-	-	158	55	119	9
704 0.70 km	ND	520	80	110	40	19	48	5
707 1.03 km	-	430	60	65	19	8	18	4
710 1.53 km	-	200	ND	ND	-	-	-	-

Note: [1]Distance of station from Blackbird Creek outfall - Stations 701-710 extend in a straight line from the effluent outfall, S.S.E., into Jackfish Bay.

ND - Not detected.

ppt or μg/ℓ - parts per trillion.

ppb or μg/ℓ - parts per billion.